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ANTISCATTER TREATMENTS FOR GLASS

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ANTISCATTER TREATMENTS OF GLASS

by

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PREFACE

The widespread use of glass in all types of buildings and transportation vehicles presented a critical problem in providing measures for protection against air raids. Glass splinters projected through the air by bomb explosions have resulted in personnel casualties, damage to machinery, and disruption of blackout facilities. At the start of the war in this country many different materials and methods were proposed for treating glass to prevent scattering. The Office of Civilian Defense requested the National Bureau of Standards to evaluate these and submit recommendations concerning their use. The results of this investigation are reported in this publication to supplement the information already distributed to State and local defense councils, Government agencies, business firms, and individual inquirers. In addition to its significance in protection against flying glass during air raids, the paper also will be of interest to manufacturers concerned with general problems relating to adhesion of materials to glass.

LYMAN J. BRIGGS, *Director.*

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ABSTRACT

The relative effectiveness of various commercial and experimental antiscatter treatments for glass was investigated at the request of the United States Office of Civilian Defense. A vacuum-concussion apparatus was used to test glass treated with lacquers, tapes, plastic films, and adhesive-fabric combinations. The materials which gave satisfactory results as initially applied were subjected to wet-dry cyclic and heat tests to determine the aging characteristics of the antiscatter materials. Only a few materials retained the particles of glass satisfactorily in the vacuum test after subjection to the two accelerated aging tests. A review is included of the experimental work and experiences of the British in developing treatments for glass to prevent it from scattering when fractured by bomb explosions.

I. INTRODUCTION

An investigation to determine the relative effectiveness of various commercial and experimental antiscatter treatments for glass was undertaken by the National Bureau of Standards at the request of the United States Office of Civilian Defense. To facilitate the work, a study was made of the results of the experiments and experiences of the British which were available in various technical publications. A short review of the more pertinent references is given in one section of this report. As a result of this study, a vacuum-concussion apparatus similar to that used by one group in England was built. The results of the tests made on this apparatus are presented in this report. In addition, results of accelerated aging tests made on the materials that gave promising results in the vacuum test are presented.

Some tests were made on special types of glass and replacements for glass in window enclosures for comparative purposes, and the results are included herein. In general, methods for protecting against flying glass that do not involve a treatment applied to the glass are not covered in this report.

II. REVIEW OF LITERATURE

Moore[1] [1] in discussing the effects of an explosion on windows observed that the effectiveness of any coating applied to the glass surface depends on (a) the adhesion of the coating to the glass and (b) the strength and toughness of the coating. Sheets of transparent cellulose, fabric, and nettings of heavy mesh were effective when bonded properly to the glass. The "all-over" treatments were superior to the tape treatments. Moore recommends that these treatments not only cover the glass completely but that they "should be carried well over and securely fixed to the edges of the window frame." Varnish and lacquer coatings, if thick enough, were effective

[1] Figures in brackets indicate the literature references at the end of this paper. A few references not cited in the text are given following the bracketed references.

when fresh. He used a round-bottom glass flask containing 2 pounds of blasting powder for his bomb.

An apparatus developed in England for studying the scattering of glass particles produced by rupturing glass by a concussion was described [2,3] in December 1940. The glass pane, which may be treated with an "antiscatter" material, is used to cover one end of a cylindrical transparent box, the other end of which is connected through a quick-acting release valve to a large evacuated chamber. When the valve is opened the sudden reduction of pressure in the transparent box gives the effect of a blow on the outside.

The results of work done by the Building Research Station (England) were reported by H. M. Llewellyn [4] in the spring of 1941. The data were obtained by high-explosive blasts and blasts from balloons filled with electrolytic gas. Liquid antiscatter treatments were found to give a good degree of protection when coatings of sufficient thickness were applied. Most of these treatments lost their initial effectiveness when exposed indoors for a short time (4 months was regarded as a minimum requirement). Transparent plastic films of adequate thickness applied to glass with suitable adhesives also gave a good degree of protection. A varnish or lacquer, which may be used as the adhesive also, needs to be applied over the film to make it waterproof. Textile fabrics when securely fastened to the glass give some protection. The application of varnish or lacquer over the fabric enhances the protective value of the treatment as well as rendering it waterproof. Experiments showed that the use of tapes was not very effective unless the tape material was very strong and closely spaced. In any case, they were less effective than the "all-over" treatments. In the discussion, it was noted that from reports received and examinations made of actual bombing damage, the use of good treatments was fully justified.

Llewellyn [5] made another report in April 1942 of the work carried out at the Building Research Station (England). He states that varnishes, lacquers, etc., "when used alone, usually proved unreliable, owing to the difficulty of obtaining a coating of sufficient thickness and one which would remain tough and elastic for a reasonably long period under normal conditions of exposure; only a small minority of those tested showed anything like satisfactory performance. Textile fabrics, on the other hand, when merely stuck to the glass with aqueous adhesives are susceptible to damp conditions; they tend to peel off and also become mildewed." Combinations of varnishes and fabrics were tested with the following results: (1) Each individual varnish-fabric combination must be tested to determine its effectiveness, (2) lacquers which deposit soft, tacky films are superior to those which give dry, hard films, and (3) the most satisfactory type of treatment consists in covering the glass with a coat of lacquer, quickly applying the fabric, allowing to dry, and finally applying another coat of lacquer.

Butterworth [6] of the Building Research Station (England) published in August 1942 a brief discussion of the theories concerning adhesion and of the properties of the various commercial types of adhesives. Although this is a general treatise on adhesives, one significant comment on antiscatter treatment is made, as follows: "Fabric-varnish treatments have in fact been used successfully for the protection of windows, notably those of passenger transport vehicles." The second part of his report [7] discusses the following properties that an adhesive should have to hold textile fabrics and transparent films to window glass: (1) It should hold the protective material to the glass with sufficient strength initially to be effective. Provided the glass is clean, there is no great difficulty in obtaining adhesion to the glass. The fabric can be imbedded in the adhesive layer to ensure its firm attachment. With regenerated cellulose sheets the choice of adhesives is severely restricted, whereas cellulose acetate film

presents an even more difficult problem. (2) It should have no effect on the strength of the fabric or film. Water-soluble adhesives reduced the strength of the transparent films. Some nonaqueous adhesives were satisfactory with films but were expensive. Fabrics are adversely affected by adhesives containing acids or oxidizing agents. (3) It should not injure the glass. Adhesives containing sodium silicate were the only ones which gave an etched appearance to the glass. Some unplasticized glues, applied hot, pluck pieces from the surface of the glass. (4) It should not become brittle or flake away from the glass on exposure. Many of the adhesives became dry and brittle and flaked off of the glass in summer weather. This is particularly true of adhesives made of vegetable gums, dextrins and animal glue. All adhesives should be adequately plasticized. (5) It should not be unduly weakened by exposure to very humid atmosphere. It is doubtful if any adhesives will retain any useful degree of adhesiveness under conditions of continuous condensation. (6) It should not encourage the growth of molds. Many aqueous adhesives are favorable media for the growth of molds, particularly when moist, in which case preservatives should be used.

In May 1942, the British Standards Institution issued a specification covering antiscatter fabrics [8]. This specification covers adhesive fabric, for use with or without a coating of protective varnish, and nonadhesive fabric, which is applied by means of a lacquer or varnish type of adhesive. The detail specifications cover weight and bursting strength of the fabric, the adhesion to glass, and resistance to mildew. It is further pointed out that varnishes or lacquers for use with fabrics must be tested and approved for this purpose. For windows not subject to condensation an adhesive made of tapioca starch mixed with one-quarter to one-third of its weight of glue is recommended. A soluble starch may be used with the glue, but the resistance to high humidities is not as good as the tapioca starch and glue mixture. Tapioca or soluble starch may be used alone, but the adhesion is not as good as that obtained with the mixtures of starch and glue. To obtain resistance to mildew, an antiseptic should be added to the adhesive. A supplement to this specification gives information that is useful in selecting and in applying antiscatter treatments to glass. Bleached and dyed fabrics are not recommended unless a dark color is necessary for blackout protection. Plain weaves not too closely woven (varnish or lacquer must penetrate readily) are recommended. Moisture resistant varnishes or lacquers should be used where condensation or high humidities are likely to be encountered. These can be used as adhesives for fabric or can be applied over an adhesive-fabric treatment. Where condensation is exceptionally heavy, the treatments should be applied to the dry side of the glass.

III. DESCRIPTION OF APPARATUS

For the tests described in this report, a vacuum-concussion apparatus was built similar in principle to one developed and used in England [2], but modified to insure rigidity of the testing frame during application of the load to the glass. This equipment, shown in figures 1 and 2, consists of a steel tank (vacuum reservoir) connected by means of pipe through a quick-acting release valve to the concussion chamber. The concussion chamber was made by welding two pieces of flat steel onto the ends of half of a 16-inch piece of 12-inch-diameter steel pipe so cut that two semicircular pieces were obtained. A steel facing frame was then welded around the opening. Another frame, identical with the one welded to the steel box, was also made to clamp the glass panel to the steel concussion chamber. These steel frames were faced with thin rubber sheeting. The glass test specimen was placed on the frame attached to the semicylindrical steel box and the clamping frame placed on top of the glass. A wire basket was placed inside

the concussion chamber to catch the glass fragments.

The reservoir was connected to a vacuum pump and to a manometer. The connections between the concussion chamber and the vacuum tank were made of 1 ½-inch pipe. The quick-acting release valve has an opening 2 inches in diameter. The lever to open the valve was operated by means of a weight attached to a small rope running over a pulley. The weight was supported by another rope attached to a pin. When the pin was knocked out, the weight dropped, thereby opening the valve. This insured the same rate of valve opening throughout the tests.

The capacities of the various parts of the apparatus are as follows:

Vacuum reservoir	5.56
Connections to pump and valve	0.06
Total volume on vacuum side	5.62
Concussion chamber	0.52
Connections to valve	.04
Total volume on concussion side	0.56

The ratio of the volume of the vacuum side to that of the concussion side is therefore 10 to 1.

IV. METHOD OF TEST

The various treatments submitted for evaluation were applied to one side of 14- by 19-inch panes of double strength, grade B window glass, the type commonly used for glazing. The test specimen was placed over the opening of the concussion chamber with the treated side of the glass pane facing inwardly and was clamped lightly between the two frames. The reservoir was evacuated to the selected manometer reading and the quick release valve was opened. The glass fragments caught in the wire basket were weighed and an estimate of the size and number of the larger pieces was made. Photographs of the specimens that held together reasonably well were made. The relative effectiveness of the treatments was judged by the types of failure and the amounts of flying glass.

Most of the tests were made at a manometer reading of 20 inches of mercury, which is equivalent to a pressure of approximately 10 lb/in^2. It was found that at a manometer reading of 15 inches, untreated double-strength window glass would always break, whereas at 14 inches the glass usually would not break. The 20 inches was selected because it was desired to break the glass in each test so that the amount of flying glass could be measured, and it was realized that the treatments might increase the breaking strength of the glass to some extent. In more than 500 tests, the double-strength window glass coated with various antiscatter treatments failed to break in only two instances at the 20-inch vacuum. Some special types of glass required more pressure to break and when this was necessary, it is indicated in the tables. The approximate air pressures on the outside of the glass corresponding to various manometer readings are as follows:

Manometer reading	Air pressure
Inches	*lb/in.^{2}*
29.9	14.7
28.0	13.8
24.0	11.8
20.0	9.8
15.0	7.4
14.0	6.9
10.0	4.9

The treatments that gave promising results in the initial vacuum tests were applied to glass and subjected to accelerated aging tests. Test I consisted in exposure to approximately 100-percent relative humidity and 70° F for 8 hours, followed by drying at ordinary interior conditions for 16 hours. This cycle was repeated 10 times. Test II consisted in continuous exposure to a temperature of 160°F in a forced-draft oven. Two different periods of exposure were used in the latter test, namely, 2 days and 7 days. Test I evaluates the treatments where the windows

to which they will be applied will be subjected to high humidities. Test II evaluates the treatments where the interior of the windows will be exposed to low relative humidities and to heat from the sun; this is probably the most common condition. After the panels were subjected to these accelerated aging conditions, they were tested on the vacuum-concussion apparatus.

V. DESCRIPTION OF MATERIALS

The various antiscatter coating materials received for test were classified into seven groups. These are listed below, together with the number of samples tested and the table references in which detailed descriptions of the samples and the results of the burst tests are presented.

Type of material	Designation of treatment	Number of samples	Sample described in table	Test results in table
Liquid	L	25	1	10, 15, 19, 25
Sheetings, plastic	S	23	2	11, 15, 20, 26
Tapes	T	36	3	12, 15, 21, 27
Fabrics	F	21	4	13, 22, 28
Asphalt-asbestos	A	4	5	14, 23, 29
Special products	P	18	6	16, 24, 30
Glass, special	G	18	7	17
Replacements for glass	R	6	8	18
Home-prepared adhesives	Z	5	9	13

A total of 156 materials were submitted for test, but many combinations were made possible by using lacquers with films, tapes, or fabrics. Many of these combinations were prepared and tested.

VI. RESULTS OF BURST TESTS

The results of the burst tests made on glass treated with the various materials are given in tables 10 to 18. It was found that the breaks could be classified into six types. The types of breaks are described as follows:

Break designation	Description
A	Glass cracked, but practically intact.
B	Glass cracked and backing material punctured; small hole in glass.
C	Glass cracked and backing material punctured; same type as B but hole larger.
D	Glass shattered and part of pane in basket; remaining part hanging in large flaps or strips.
E	Glass shattered and most of pane in basket.
F	Glass shattered badly and separated from plastic backing, but backing material did not break and hence kept glass from falling into the basket.

The best type of break is A; next best, B; etc., up to E, inclusive. F is misleading when only the amount of glass thrown into the basket is considered. The film might break in an actual bomb explosion which would result in the F type becoming an E type break.

For purposes of studying the data in the tables, the following tentative basis is used:

Type of break	Break designation	Amount of glass in basket
		Grams
Good	A, B, C	0 to 20
Bad	D, E, F	>20

It should be noted that when a treatment is placed in the "good break" group here on the basis of these initial tests, it may be construed as meaning that the treatment is satisfactory if it also has satisfactory aging properties. Those placed in the "bad break" group certainly cannot be considered effective in any case.

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Some lacquers meet the requirements of the good break group when applied in thicknesses of 12 mils or more; others do not meet these requirements regardless of the thickness (table 10). The effect of thickness on the type of break is illustrated in figure 3.

Film sheetings of the vinyl acetal type, ranging in thickness from 15 to 60 mils, met the requirements of the good break group (table 11). These film sheetings, in all cases but one, were applied to the glass by the manufacturers.

Tests were made on a 2.5-mil sheeting of regenerated cellulose having a water-soluble adhesive on one side (table 11). Some test specimens were prepared by applying the sheeting to the glass with water, and others with a warm iron. The film thickness was increased by applying several sheets, one over the other. This material in thicknesses from 2.5 to 15 mils did not give good breaks. The one case in which the material did give a good break could not be duplicated. This sheeting was also tested in combination with lacquers; these results are discussed in another paragraph in this section of the report.

A transparent film, 2 mils thick, with a pressure-sensitive adhesive was tested and failed (table 11).

Few of the tapes tested gave good breaks (table 12). Those tapes which did pass were applied as an over-all treatment in which the strips were lapped. In some instances better results were obtained when a narrow slit was cut in the middle of the tape layer or when a double Y pattern, >——<, was cut in the tape layer. The results of some of these tests on tapes are shown in figures 4 and 5.

The results of tests made on combinations of fabrics with lacquers and water-soluble adhesives indicate that such combinations give good breaks in only a few instances (table 13). One lace type fabric used with lacquers L-EI-2 and L-GI-2 in film thicknesses of 15 mils gave good breaks. However, these lacquers gave similar results when tested without fabric. One water-soluble adhesive, a tapioca-glue mixture, used in combination with two fabrics, gave good breaks, but it has a disadvantage in that it chips the surface of the glass. Lacquers that gave bad breaks when tested independently, also failed when tested in combinations with fabrics. Some lacquers which passed when tested independently failed when tested with some fabrics, probably because the lacquer film was too thin. This leads to the conclusion that each fabric lacquer combination must be considered individually. The effect obtained with one fabric bonded to the glass with various adhesives is shown in figure 6.

Tests were made on four types of asphalt-asbestos combinations that had been applied to the glass by the manufacturer (table 14). Three of the four gave good breaks; the fourth failed by a small margin.

Tapes, film sheetings and lacquers, which, with the exception of the cellulose acetate film, were tested separately, were also tested in various combinations (table 15). The cellulose acetate sheetings were tested in combination with several lacquers, and the results indicate that the effectiveness of such combinations is largely dependent on the lacquer used as the adhesive. When an adequate thickness is used the combination of sheeting and a lacquer passes if the lacquer alone passes the test. If the lacquer, when used by itself, fails, the combination employing this lacquer with tapes and films will also fail. Although the use of a tape or film with a good lacquer may result in a combination which passes, the thickness required to pass is so great that there is little advantage in these combinations. In the use of opaque tapes and fabrics, the decrease in light transmission may be an important factor.

Vinyl acetal resin film, previously discussed with respect to its application to double-strength window glass was also applied to single-strength glass, ¼-inch

plate glass, and ¼-inch tempered glass by manufacturers in their laboratories (table 16). The film thicknesses of these sheetings varied from 8 mils on some single-strength glass to 60 mils on the plate and tempered glass. Most of the treatments gave good breaks, although some of those applied to the ¼-inch plate glass gave bad breaks. The plate glass in most instances did not break at a manometer reading of 20 inches but required 28 inches. The tempered glass could not be broken on the vacuum-concussion apparatus.

For purposes of comparison with treated and untreated double-strength window glass, tests were made on various types of glass (table 17). All but two of these gave bad breaks; the two which gave good breaks involved the use of plastic film. The tempered glass could not be broken even with a pressure differential of 28 inches of mercury and therefore could not be rated.

Three replacement materials for glass windows were tested (table 18). One was a combination of wire screen and transparent plastic, another cotton scrim coated with a thin layer of transparent plastic, and the other a combination of asphalt, asbestos, and paper. The wire and scrim materials and all except one of the asphalt-asbestos-paper combinations gave good breaks.

VII. RESULTS OF ACCELERATED AGING TESTS

Many of the antiscatter materials which gave good breaks were put through the two accelerated aging tests described in section IV to determine their performance after exposure to ordinary indoor conditions of temperature and humidity. The materials selected for accelerated aging were applied to the glass in the combinations and thicknesses that gave the best results in the initial vacuum-impact tests. Many of the treatments applied by the manufacturers were not aged because some of them were very much alike, e.g., identical materials applied in various thicknesses. The results of these tests are presented in tables 19 to 30.

Failure of antiscatter material as a result of exposure to cycles of high and low humidity (accelerated aging test I) was always associated with a loosening of the bond between the glass and the backing material, as evidenced by shrinkage, roughening, and peeling of the material.

Heat aging caused many failures of the backing material tested, apparently because of loss of flexibility. The materials that passed may be divided into two classes: (1) Plastic materials of a rubber-like consistency which did not become brittle as a result of heat, and (2) fabrics and fabric tapes applied to the glass with water-soluble adhesives. Although the water-soluble adhesives may themselves have become brittle, apparently they did not penetrate the fiber sufficiently to impair the flexibility of the fabric.

These accelerated aging tests indicate that many of the treatments will not have good aging properties. Only 6 of the 26 treatments tested, not counting those applied by the manufacturers, maintained their effectiveness on exposure to the accelerated aging tests.

The results of all the tests made on the antiscatter materials may be summarized briefly as follows:

	Liquid materials	Film sheetings	Tapes	Fabric-adhesive combination	Asphalt-asbestos
Number of materials tested initially in vacuum chamber...	24	19	32	52	4
Number of materials which gave good breaks initially.....	10	13	3	12	2
Number subjected to the humidity accelerated aging test..	6	9	9	5	4
Number giving good breaks after humidity exposure........	3	7	3	4	2
Number subjected to heating accelerated aging test.......	5	7	8	6	4
Number giving good breaks after exposure to dry heat.....	2	4	1	3	2
Number giving good breaks after exposure to both accelerated aging tests....................................	2	4	1	3	1

VIII. DISCUSSION

Experience in England indicates that short of blocking up the window with brick, thick timbers, or heavy steel, it is practically impossible to reinforce the glass to such an extent that it will not break. Consequently, it can be assumed that any treatments that may be applied to windows in homes, offices, schools, etc., cannot keep the glass from breaking. The problem resolves itself, therefore, into one of finding a treatment for glass which (1) will not allow much glass to fly when the glass breaks, (2) will reduce the velocity of the particles of glass which do fly, and (3) will be strong enough to hold most of the pane in one piece or a few large pieces if the blast is strong enough to blow the window out completely.

The degree of effectiveness in actual service of any antiscatter treatment is difficult to evaluate because of the nature of the destructive wave emanating from an explosion. The wave starts in a small area and expands, and as it expands the intensity decreases. The contour of the land and obstructions, such as buildings, will effect the distribution of the forces in the wave, resulting in irregularities. It appears that nothing will withstand the shock at or very near the area (I, fig. 7) where the explosion takes place.

In an annular area (II, fig. 7) adjoining the explosion area, any treatment applied to glass will not give protection. It seems reasonable that there must be some area (III, fig. 7) beyond this one in which the wave is strong enough to break and scatter ordinary untreated window glass but not strong enough to scatter appreciably glass that is protected with a good antiscatter treatment.

It is believed that the results obtained with the vacuum-concussion apparatus evaluate the effectiveness of a treatment for use at some distance away from the center of the explosion. It is impossible to place even approximately the distance from the explosion where a treatment would be effective, since the force of the explosion of a bomb varies, depending on many factors. However, it can be assumed that treatments which do not give good results in this test will not be effective at any reasonable distance. The treatments which give good results should give some measure of protection over part of the area affected by the explosion, although it must not be assumed that any treatment will give complete protection. It is recommended that individuals take shelter, wherever possible, away from glass-enclosed spaces, even though the glass may be covered with an antiscatter treatment similar to one of the types tested in this investigation.

Based on the results obtained in this investigation on treatments applied and tested without aging, the following were found to be the most effective of those which could be applied to glass already installed. The designating letters are those used in tables 1 through 9, which describe the treatments.

1. Lacquers—minimum thickness of film, 12 mils:

L-AR-5	L-FC-1	L-NS-1	L-EI-3
L-EI-1	L-GI-1	L-NS-2	
L-EI-2	L-GI-2	L-PP-1	

2. Sheeting, plastic:

S-EI-1

3. Tapes—applied as over-all treatments:

T-GP-3
T-GP-4
T-MM-9

4. Combinations of adhesives or lacquers with sheetings, tapes, and fabrics:

L-NS-3 and S-CC-1
L-GI-1 and T-MM-9
L-SC-1 and T-GP-3
F-MP-1 and F-MA-2
F-AR-1 and F-MA-1
L-EI-2 and F-MF-2
L-GI-1 and F-MF-2
Z-4 and F-MF-2
Z-4 and F-XX-3
Z-5 and F-XX-3

Lacquer treatments and fabric-adhesive treatments predominate in this group of materials, which are effective as initially applied. The Z-4 and Z-5 adhesives cannot be recommended, since they deface the glass permanently, i.e., they break pieces out of the surface of the glass on drying.

To be considered satisfactory, an antiscatter treatment must retain its effectiveness for a reasonable length of time under normal aging. The accelerated aging methods used in the work reported herein give some indication of aging resistance of a treatment. Method I (wet-dry cycles) evaluates materials for use on windows subject to wetting with condensed moisture, e.g., windows in homes during cold weather. Method II (baking) evaluates materials for use in windows subject to dry heat, e.g., windows exposed to the rays of the sun in the summer.

Of the treatments subjected to the accelerated aging tests, the following were found to maintain satisfactory breaking characteristics after exposure to both sets of aging conditions listed above:

1. Liquid treatments—minimum thickness of film 20 mils:

   L-GI-1
   L-GI-2

2. Tapes—applied as over-all treatments:

   T-GP-4

3. Combinations:

   L-EI-2 and F-MF-2

The results of the tests on the glass panes that were coated with lacquer may be broken down as shown in table 31. These data show that of the 10 lacquers which gave good breaks initially, five were polyvinyl butyral, three polyvinyl acetate, one cellulose nitrate, and one a protein. The two which gave good breaks after aging were polyvinyl butyral lacquers. It should also be noted that the lacquer of the fabric-lacquer combination which gave good breaks after aging was based on polyvinyl butyral.

Since all the treatments depend to some extent on the action of an adhesive, the following general remark on this subject seems pertinent. For effective treatment the adhesive should remain tacky after the solvent has escaped; this will hold the glass particles to the adhesive film when the glass is shattered. In addition, the film must be strong enough so that large pieces do not tear loose. Although tacky films are generally weak, the strength necessary for effective results may be obtained by using an adhesive layer of adequate thickness or by reinforcing the adhesive.

It was observed that when the glass breaks readily there is less tendency for the glass particles to separate from the plastic.

In most cases more coats of lacquer are required to obtain an effective treatment than the number recommended by the manufacturers. The number of coats necessary to obtain the minimum thickness will vary with the individual lacquer; the thickness of the coat deposited is a function of the solids content and the viscosity of the solution.

The method of applying an antiscatter treatment is an important factor in obtaining the maximum effectiveness. The treatment should be applied on the frame beyond the glass area, so that the pane will not break along the edge where there is no application. When the glass breaks along the entire edge, the whole pane is likely to be blown into the room by the blast.

Any antiscatter treatment applied to glass will reduce the light transmission. This is particularly true of fabrics and tapes applied as over-all treatments.

IX. SUMMARY

1. The vacuum-concussion apparatus used to evaluate the effectiveness of antiscatter treatments applied to glass is described in this report. The results of tests of various types of materials to determine their

suitability as antiscattering agents are reported.

2. Some of the liquid materials (lacquers) gave satisfactory results as initially applied when the film thicknesses were 12 mils or greater.

3. None of the tapes gave satisfactory results when applied in patterns which cover only part of the glass. Three tapes gave satisfactory results as initially applied when all of the glass was covered by the material.

4. Some adhesive-fabric combinations gave satisfactory results as initially applied. The effectiveness of a particular combination cannot be evaluated from the behavior of the adhesive separately or the fabric with other adhesives. Each combination must be tested to determine its antiscatter effectiveness.

5. Antiscatter treatments must maintain their protective action after a reasonable aging period in order to be suitable for general use. Wet-dry cyclic and heat tests were made to determine the aging characteristics of the various types of antiscatter materials. Only a few materials gave satisfactory results after subjection to the accelerated aging test. The lacquers which gave "good breaks" after aging were made with polyvinyl butyral.

6. It should be recognized that no antiscatter treatment can be expected to give complete protection from the hazards of flying glass.

X. REFERENCES

[1] H. Moore, *Physics and windows in war-time*, J. Sci. Instruments 17, 237-241 (Oct. 1940).

[2] Anonymous, *Thermoplastics under vacuum*, Plastics 4, 263 (Dec. 1940).

[3] Anonymous, *Blast tests on glass*, Plastics 5, 23-25 (Feb. 1941).

[4] H. M. Llewellyn, *Antiscatter treatments for windows*, Chemistry and Industry 60, 433-4 (June 7, 1941).

[5] H. M. Llewellyn, *The testing of varnishes for use in conjunction with antiscatter fabrics*, J. Soc. Chem. Ind. 61, 60-63 (April 1942).

[6] B. Butterworth, *Adhesion and adhesives, with special reference to antiscatter treatments for windows. Part I. Adhesion and adhesives*, Chemistry and Industry 61, 339-341 (Aug. 8, 1942).

[7] B. Butterworth, *Adhesion and adhesives, with special reference to antiscatter treatments for windows. Part II. Properties required in adhesives for window protection*, Chemistry and Industry 61, 350-51 (Aug. 15, 1942).

[8] British Standard Specification (ARP Series) for Antiscatter Fabrics, BS/ARP45 (May 1942). Prepared by the British Standards Institution at the request of the Ministry of Home Security.

Additional References

H. Schardin, D. Elle, and W. Struth, On the *propagation of shattering in glass and in glass substitutes*, Z. Tech. Phys. 21, 393-400 (1940).

Anonymous, *Windows and bomb blast*, Nature 146, 435-6 (Sept. 28, 1940).

Anonymous, *The protection of windows against air-raid damage*, Engineering 150, 275-7 (Oct. 4, 1940).

D. Bernal, *The physics of air raids*, (report of a lecture) Engineering 150, 514 (Dec. 27, 1940).

R. J. Moore and H. W. Mackinney, *Information on flexible transparent and translucent substitutes for window glass*, Trans. Am. Inst. Chem. Eng. 38, 237-244 (Feb. 1942).

Anonymous, *Testing window glass for concussion damage*, Eng. News-Record 128, 521 (April 2, 1942).

Glass and Glass Substitutes, prepared under direction of Chief of Engineers, U. S. Army, for the United States Office of Civilian Defense, Protective Construction Series No. 1, for sale by the Superintendent of Documents, Washington 25, D. C., for 10 cents.

O. Petzold, Anti-Splinter Coatings for Glass, The Oil and Colour Trades Journal 98, 144-45, 180-84, 259-60, 330-31, 471-72, 611, 613, 763-65 (July 26, Aug. 2, 16, 30, Sept. 27, Oct. 28, and Nov. 22, 1940).

F. W. Adams, Behavior of Glazing Material Subjected to Explosion, ASTM Bul. No. 122, p. 15-23 (May 1943).

ILLUSTRATIONS
and
TABLES

(11)

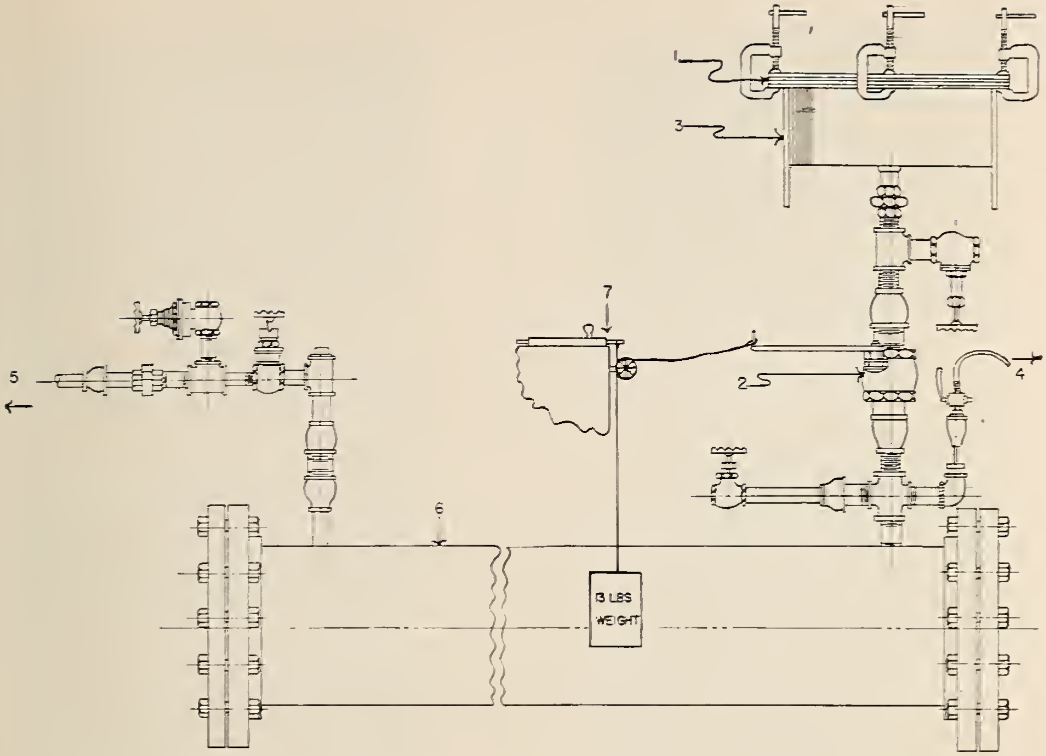

FIGURE 1.—*Diagram of vacuum-concussion apparatus.*

1, Specimen; 2, quick-acting release valve; 3, concussion chamber; 4, to manometer; 5, to vacuum pump; 6, vacuum storage tank; 7, trigger mechanism for quick-acting release valve.

FIGURE 2.—*Vacuum-concussion apparatus.*

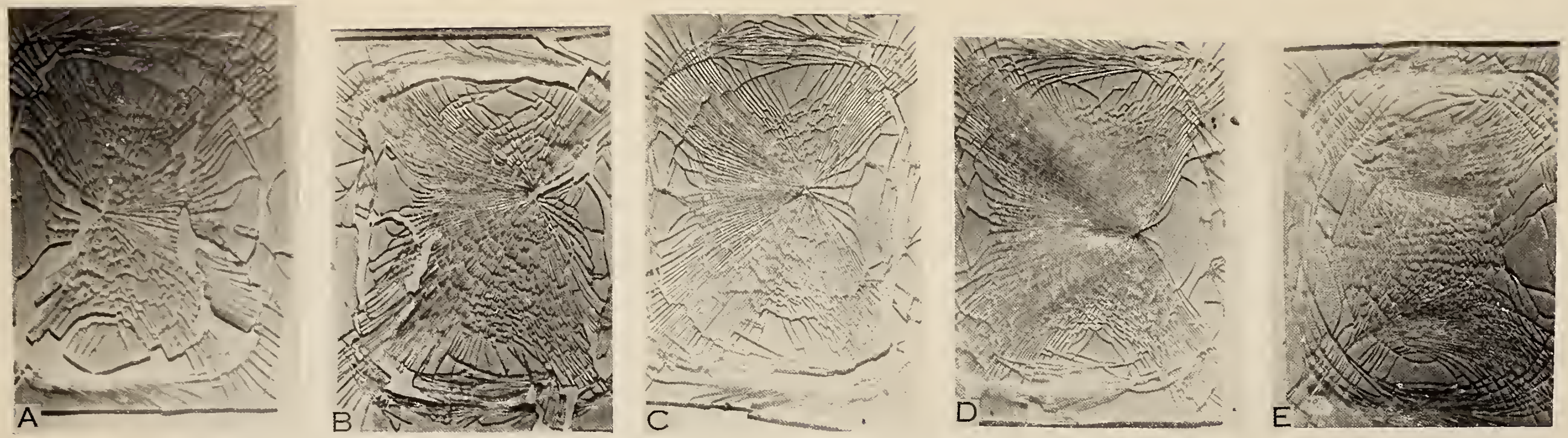

FIGURE 3.—*Antiscatter effectiveness of various film thicknesses of lacquer L–GI–1.*

A, 3 mils; B, 6 mils; C, 10 mils; D, 15 mils; E, 20 mils.

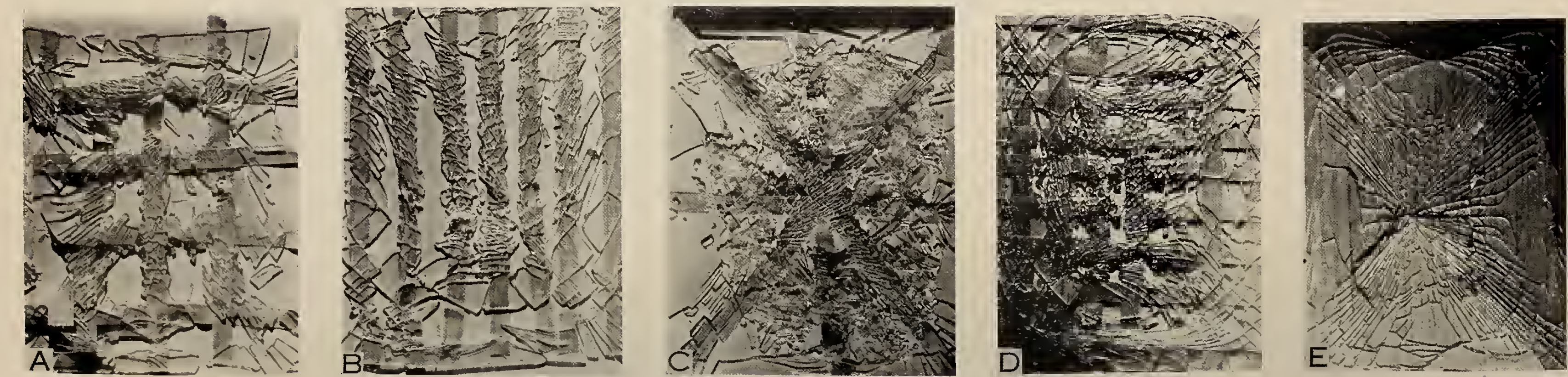

FIGURE 4.—*Antiscatter effectiveness of various patterns obtainable with tape T–GP–3.*

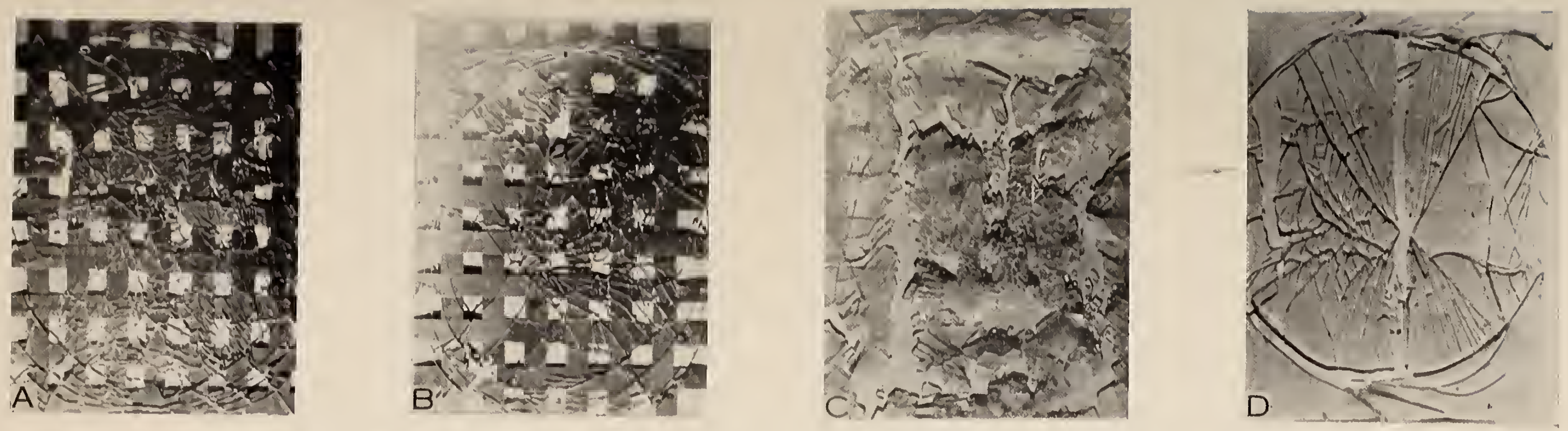

FIGURE 5. *Antiscatter effectiveness of various tapes applied in a criscross pattern.*

A, T MS-1; B, T-GP-1; C, T MM 1; D, T IP 3.

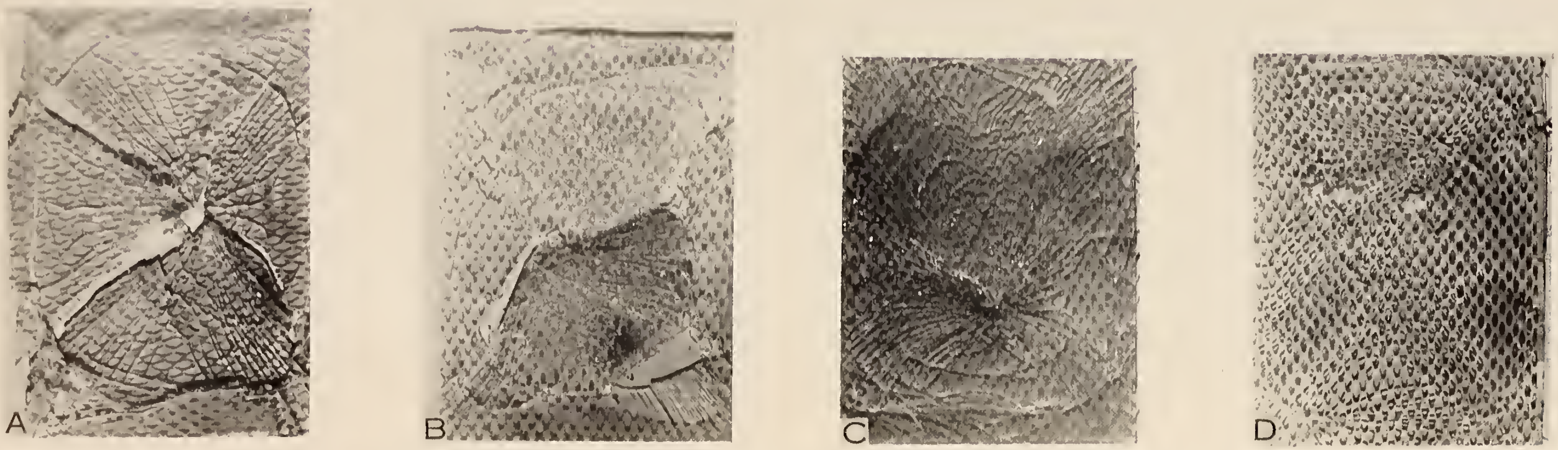

FIGURE 6.—*Antiscatter effectiveness of fabric netting F MF-2, applied with various adhesives.*

A, F–AR-1; B, L RF–2; C, L GI-1; D, L–EI-2.

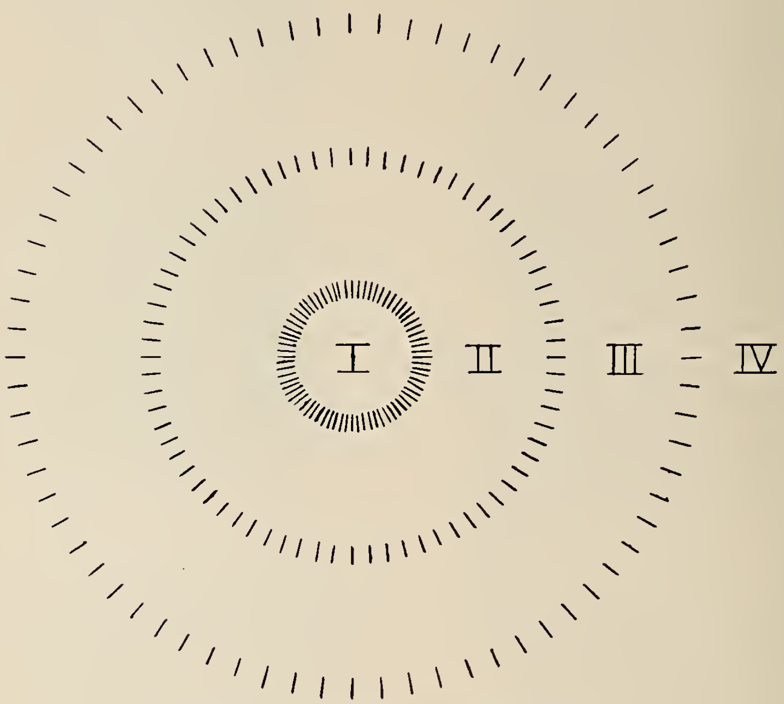

FIGURE 7.—*Explosion-area diagram.*

I. Area of explosion; walls will not withstand this force.
II. Windows blow out regardless of treatment.
III. All ordinary window glass broken. Untreated glass scattered. Glass covered with a good treatment scattered only a small amount. Some types of glass, e. g., tempered and heavy plate, may not break.
IV. Glass may or may not be broken, depending on the type of glass and treatment.

XI. TABULATION OF DATA

In the accompanying tables 1 to 31, inclusive, the following letters are used to designate the types of treatments noted:

A = Asphalt-asbestos.
F = Fabrics.
G = Glazing materials (glass) other than double strength window glass. Not treated.
L = Commercial liquid materials.
P = Treatments applied to other than double strength window glass.
R = Glazing materials, plastic.
S = Sheetings or films, plastic.
T = Tapes.
Z = Home-formulated adhesives for fabrics.

TABLE 1.—*Description of liquid materials tested for antiscatter effectiveness*

Sample designation	Description of material	Sample designation	Description of material
L-AA-1..	Opaque, black, reclaimed-rubber dispersion.	L-IX-1..	Transparent, colorless chlorinated rubber lacquer.
L-AR-1..	Transparent, colorless acrylic resin lacquer.	L-MC-1..	Transparent, colorless polyvinyl butyral lacquer.
L-AR-2..	Do.		
L-AR-3..	Transparent, colorless ethylcellulose lacquer.	L-NS-1..	White, creamy, polyvinyl acetate adhesive; dries clear.
L-AR-4..	Transparent, colorless polyvinyl acetate lacquer.	L-NS-2..	Translucent, brown protein glue; applied in hot aqueous solution.
L-AR-5..	White, creamlike, cellulose nitrate emulsion; dried colorless and transparent.	L-NS-3..	White, creamy, polyvinyl acetate adhesive; dries clear.
L-CP-1..	Transparent, colorless ethylcellulose lacquer.	L-PP-1..	Transparent, colorless polyvinyl acetate lacquer.
L-CP-2..	Do.		
L-EI-1..	Transparent, colorless, polyvinyl butyral lacquer.	L-RF-1..	Transparent, colorless polyvinyl butyral lacquer.
L-EI-2..	Do.	L-RF-2..	Transparent, colorless ethylcellulose lacquer.
L-EI-3..	Do.	L-RM-1..	Transparent, colorless lacquer.
L-FC-1..	Transparent, colorless polyvinyl acetate lacquer.	L-SC-1..	Do.
L-GI-1..	Transparent, colorless polyvinyl butyral lacquer.	L-WP-1..	Do.
L-GI-2..	Same as L-GI-1, except more viscous (higher solids content).	L-WW-1..	Transparent, colorless ethylcellulose lacquer.

TABLE 2.—*Description of plastic sheetings tested for antiscatter effectiveness*

Sample designation	Description of material
S-CC-1.........	Transparent, colorless cellulose acetate.
S-CC-2.........	Do.
S-DC-1.........	Transparent, colorless, thin cellulosic plastic sheet.
S-EI-1.........	Translucent, colorless, 15-mil-thick vinyl butyral resin sheet.
S-EI-2.........	Transparent, colorless, 5-mil-thick vinyl butyral resin sheet.
S-EI-3.........	Transparent, colorless, 10-mil-thick vinyl butyral resin sheet.
S-EI-4.........	Transparent, colorless, 15-mil-thick vinyl butyral resin sheet.
S-EI-5.........	Transparent, colorless, 20-mil-thick vinyl butyral resin sheet.
S-EI-6.........	Transparent, colorless, 25-mil-thick vinyl butyral resin sheet.
S-LO-1.........	Transparent, colorless, rubbery, 20-mil-thick vinyl butyral resin sheet.
S-LO-2.........	Transparent, colorless, rubbery, 30-mil-thick vinyl butyral resin sheet.
S-LO-3.........	Transparent, colorless, rubbery, 45-mil-thick vinyl butyral resin sheet.
S-LO-4.........	Transparent, colorless, rubbery, 60-mil-thick vinyl butyral resin sheet.
S-LO-5.........	Transparent, colorless, rubbery, 15-mil-thick vinyl butyral resin sheet.
S-MC-1.........	Translucent, rubbery, 25-mil-thick vinyl butyral resin sheet.
S-MC-2.........	Translucent, rubbery, 25-mil-thick vinyl butyral resin sheet covered with a layer of thin cellulose acetate sheet.
S-MC-3.........	Translucent, rubbery, 15-mil-thick vinyl butyral resin sheet.
S-MC-4.........	Translucent, rubbery, 15-mil-thick vinyl butyral resin sheet covered with a layer of thin cellulose acetate sheet.
S-MC-5.........	Translucent, rubbery, 8-mil-thick vinyl buytral resin sheet.
S-MC-6.........	Translucent, rubbery, 8-mil-thick vinyl butyral resin sheet covered with a layer of thin cellulose acetate sheet.
S-MC-7.........	Transparent, colorless thin cellulose acetate sheet.
S-SI-1.........	Transparent, colorless regenerated cellulose sheet coated on one side with a water-soluble adhesive.
S-TP-1.........	Transparent, colorless, thin cellulosic plastic sheet; pressure-sensitive adhesive.

TABLE 3.—*Description of tapes tested for antiscatter effectiveness*

Sample designation	Description of material
T-GP-1	Opaque, brown, 1"-wide paper; water-soluble adhesive.
T-GP-2	Opaque, brown, 2"-wide paper; water-soluble adhesive.
T-GP-3	Opaque, tan-white tweed, 1" cloth; water-soluble adhesive.
T-GP-4	Opaque, tan-white tweed, 2" cloth; water-soluble adhesive.
T-GP-5	Opaque, brown, 1"-wide, 35-lb paper; water-soluble adhesive.
T-GP-6	Opaque, brown, 1"-wide, 60-lb paper; water-soluble adhesive.
T-GP-7	Opaque, brown, 1"-wide, 90-lb paper; water-soluble adhesive.
T-IP-1	Transparent, colorless, 1"-wide thin plastic sheeting; pressure-sensitive adhesive.
T-IP-2	Transparent, colorless, 3/4"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-3	Transparent, colorless, 1"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-4	Transparent, colorless, 1 1/8"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-5	Transparent, colorless, 1 1/2"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-6	Transparent, colorless, 2"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-7	Transparent, colorless, 4"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-8	Transparent, colorless, 2"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-9	Transparent, colorless, 4"-wide, thin plastic sheeting; pressure-sensitive adhesive.
T-IP-10	Opaque, brown, 2"-wide paper; pressure-sensitive adhesive.
T-IP-11	Opaque, black, 1 1/2"-wide, thin plastic sheeting; pressure sensitive adhesive.
T-MM-1	Translucent, gray, 1"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MM-2	Translucent, gray, 2"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MM-3	Translucent, gray, 4"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MM-4	Opaque, black, 2"-wide paper, photographic; pressure-sensitive adhesive.
T-MM-5	Opaque, white, rough grain, 2"-wide paper masking; pressure-sensitive adhesive.
T-MM-6	Opaque, black, 2"-wide paper, photographic; pressure-sensitive adhesive.
T-MM-7	Translucent, white, 4"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MM-8	Translucent, colorless, 4"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MM-9	Do.
T-MM-10	Transparent, colorless, 4"-wide cellophane; pressure-sensitive adhesive.
T-MM-11	Transparent, colorless, 4"-wide cellulose acetate and cellulose fiber; pressure-sensitive adhesive.
T-MS-1	Opaque, brown, 1"-wide paper with white cord sewn down middle; water-soluble adhesive.
T-MS-2	Opaque, brown, 2"-wide paper with white cord sewn down middle; water-soluble adhesive.
T-MS-3	Opaque, brown, 1"-wide paper with white rope sewn down middle; water-soluble adhesive.
T-MS-4	Opaque, brown, 2"-wide paper with white rope sewn down middle; water-soluble adhesive.
T-PB-1	Transparent, colorless, 2"-wide cellulose acetate; pressure-sensitive adhesive.
T-PB-2	Opaque, yellow, 1"-wide, cellophane; pressure-sensitive adhesive.
T-PB-3	Opaque, white, 2"-wide fabric, surgeons; pressure-sensitive adhesive.

TABLE 4.—*Description of fabrics and adhesives specified for fabrics tested for antiscatter effectiveness*

Sample designation	Description of materials	Sample designation	Description of materials
F-AM-1	White, close-weave, stiff scrim.	F-MC-1	White, close-weave scrim impregnated with polyvinyl butyral.
F-AB-1	Opaque, brown vegetable adhesive.	F-MF-1	White, small mesh lace curtain.
F-CS-1	Opaque, black paper, adhesive on one side.	F-MF-2	White, large mesh lace curtain.
F-DC-1	White, 1/4-in. netting.	F-MP-1	Opaque, grey-brown liquid.
F-II-1	White, large mesh lace.	F-NS-1	Opaque, white, wet-converted starch paste.
F-II-2	Green, 1/4-in. netting.	F-NS-2	Opaque, white, vegetable-base plastic adhesive.
F-LO-1	Black, close-weave scrim.	F-NS-3	Opaque, brown, vegetable-base plastic adhesive.
F-MA-1	Brown, close-weave, heavy needlepoint canvas.	F-NS-4	Opaque, tan, plasticized flour paste.
F-MA-2	Brown, close-weave, heavy needlepoint canvas, one coat of plastic.	F-XX-1	Natural, cheesecloth.
F-MA-3	Brown, close-weave, heavy needlepoint canvas, two coats of plastic.	F-XX-2	Green, 1/4-in. netting.
		F-XX-3	Natural, close-weave muslin.
		F-XX-4	Natural, 3/32-in. netting.

TABLE 5.—*Description of asphalt-asbestos combinations tested for antiscatter effectiveness*

Sample designation	Description of material
A-SM-1	Opaque, black, 6-lb reinforced asbestos paper, asphalt-clay emulsion adhesive.
A-SM-2	Opaque, black, asphalt cutback base coating with asbestos fiber filler.
A-SM-3	Opaque, black, 50-lb unsaturated rag felt, asphalt-clay emulsion adhesive.
A-SM-4	Opaque, black, 15-lb asphalt saturated rag felt, asbestos fiber and asphalt-cement adhesive.

TABLE 6.—*Description of treatments applied to single strength window glass, 7/32-inch glass, plate glass, and tempered glass, and tested for antiscatter effectiveness*

Sample designation	Description of material
P-AW-1	Opaque, black paint, applied over transparent, colorless, polyvinyl butyral lacquer, applied to 7/32" glass.
P-LO-1	Transparent, colorless, 30-mil-thick polyvinyl butyral resin sheet applied to single-strength window glass.
P-LO-2	Transparent, colorless, 45-mil-thick polyvinyl butyral resin sheet applied to single-strength window glass.
P-LO-3	Transparent, colorless, 60-mil-thick polyvinyl butyral resin sheet applied to single-strength window glass.
P-LO-4	Transparent, colorless, 20-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick plate glass.
P-LO-5	Transparent, colorless, 30-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick plate glass.
P-LO-6	Transparent, colorless, 45-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick plate glass.
P-LO-7	Transparent, colorless, 60-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick plate glass.
P-LO-8	Transparent, colorless, 15-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick plate glass.
P-LO-9	Transparent, colorless, 20-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick tempered glass.
P-LO-10	Transparent, colorless, 15-mil-thick polyvinyl butyral resin sheet applied to 1/4"-thick tempered glass.
P-LO-11	Black, close-weave scrim impregnated with polyvinyl butyral resin applied to 1/4"-thick plate glass.
P-MC-1	Translucent, colorless, 25-mil-thick polyvinyl butyral resin sheet applied to single-strength-window glass.
P-MC-2	Translucent, colorless, 25-mil-thick polyvinyl butyral resin sheet covered with a layer of thin cellulose acetate sheet and applied to single-strength window glass.
P-MC-3	Translucent, colorless, 15-mil-thick polyvinyl butyral resin sheet applied to single-strength window glass.
P-MC-4	Translucent, colorless, 15-mil-thick polyvinyl butyral resin sheet, covered with a layer of thin cellulose acetate sheet and applied to single-strength window glass.
P-MC-5	Translucent, colorless, 8-mil-thick polyvinyl butyral resin sheet, applied to single-strength window glass.
P-MC-6	Translucent, colorless, 8-mil-thick polyvinyl butyral resin sheet covered with a layer of thin cellulose acetate sheet, and applied to single-strength window glass.
P-MC-7	White, close-weave, scrim impregnated with polyvinyl butyral resin and applied to single-strength window glass.

TABLE 7.—*Description of special glass products tested for scatter resistance*

Sample designation	Description of material
G-AW-1	Double-strength window glass, 1/8" thick.
G-PG-1	Single-strength window glass, 3/32" thick.
G-PG-2	Double-strength window glass, 1/8" thick.
G-PG-3	Heavy window glass, 3/16" thick.
G-PG-4	Plate glass, 1/4" thick.
G-LO-1	Tempered glass, 1/4" thick.
G-PG-5	Do.
G-MG-1	Wire glass, 1/4" thick.
G-MG-2	Translucent wire glass, 1/4" thick.
G-AW-2	Laminated glass, one pane single-strength and the other pane double-strength window glass.
G-AW-3	Laminated glass, one pane, 7/32" thick; other pane, lantern-slide glass.
G-LO-2	Laminated glass, one pane each, 1/8"-thick tempered glass, 1/8"-thick heat-treated glass, 1/8"-thick tempered glass, 1/4"-thick tempered glass, three plastic interlayers.
G-PG-6	Laminated glass, two panes 1/8"-thick photo glass.
G-PG-7	Laminated glass, two panes of either single-strength or double-strength window glass.
G-PG-8	Laminated glass, one pane 5/32"-thick window glass, other pane 7/32"-thick window glass.
G-PG-9	Laminated glass, one pane 7/32"-thick window glass, other pane 9/32"-thick window glass.
G-AW-5	Single-strength glass, two panes coated with polyvinyl butyral plastic on sides facing out, 1/2" air space between two panes.

TABLE 8.—*Description of replacements for glass in window enclosures tested for blast resistance*

Sample designation	Description of material
R-JM-1	Opaque, black, 1/8"-thick asphalt board containing organic-fiber reinforcing and mineral matter.
R-JM-2	Opaque, black, 1/8"-thick, 3-ply construction—asbestos felt, rag felt, and asbestos paper.
R-JM-3	Opaque, black, 9/64"-thick, 4-ply construction—asbestos felt, 2 rag felt, and asbestos paper.
R-MC-1	Transparent, colorless, cellulose acetate sheet reinforced with metal screening.
R-WS-1	Do.

TABLE 9.—*Description of pastes readily prepared in the home*

Sample designation	Description of materials
Z-1	*Flour paste:* Prepared by heating with constant stirring, a mixture of flour and water in the following proportions: 1 lb of flour, 1 gal of water. A small amount of cold water is mixed with the flour and the rest of the water heated to boiling. The flour and cold-water mixture is added to the boiling water and heated until thickened.
Z-2	*Tapioca paste I:* Prepared by heating with constant stirring, a mixture of tapioca starch, phthalic anhydride, and water in the following proportions: 1 lb of tapioca starch, 0.2 oz of phthalic anhydride, 8 lb of water.
Z-3	*Tapioca paste II:* Prepared by heating with constant stirring, a mixture of potato starch, tapioca starch, alum, and paraformaldehyde in the following proportions: 1.9 lb of potato starch, 5.4 lb of tapioca starch, 0.03 lb of alum, 0.02 lb of paraformaldehyde, 8 lb of water.
Z-4	*Tapioca-glue combination I:* Prepared by heating with constant stirring, a mixture of tapioca starch, animal glue, and water in the following proportions: 1 lb of tapioca, 1/3 lb of animal glue, 2 lb of water.
Z-5	*Tapioca-glue combination II:* Prepared in the same manner as Z-4, using instead 1/4 lb of glue to 1 lb of tapioca starch.

TABLE 10.—*Vacuum-impact tests made on glass treated with liquid materials*

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
L-AR-1	One coat applied with a doctor blade	12 to 14	E	780
L-AR-2	....do	11	E	848
L-AR-3	Two coats applied with a doctor blade	9.5	E	960
L-AR-4	....do	11.5	E	830
L-AR-5	One coat applied with a doctor blade	18	C	15
L-CP-1	One coat brushed on	4.5	E	925
	Two coats brushed on	5.5	E	312
	Six coats brushed on; dried 2 weeks	17	E	665
	Five coats brushed on	11	D	6
L-CP-2	Two coats brushed on	15	C	24
	....do	15	D	19
L-EI-2	One coat applied with doctor blade; second coat brushed on	25	A	<1
L-EI-1	One coat applied with doctor blade	25	A	<1
L-EI-3	Two coats brushed on	12	C	5
	Four coats brushed on	19	A	<1
L-FC-1	One coat applied with doctor blade	10	F	6
	Three coats brushed on	18	A	<1
L-GI-1	One coat brushed on	1.5	E	456
	....do	3.5	E	800
	....do	5.5	F	12
	....do	6	F	12
	Two coats brushed on	6	E	800
	One coat brushed on	7.5	F	25
	Two coats brushed on	10	D	10
	....do	12	A	<1
	....do	14.5	C	8
	Three coats brushed on	15	A	<1
	....do	20	A	<1
	....do	19	A	7
	Three coats brushed on; dried 2 weeks	24	A	3

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 10.—*Vacuum-impact tests made on glass treated with liquid materials*—Continued

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
L-AA-1..	Three coats brushed on	11	E	908
L-G1-2..	One coat brushed on	15.5	B	6
	.....do	19	A	<1
	One coat brushed on; dried 2 weeks	33	B	17
L-IX-1..	Six coats brushed on	10.5	E	880
L-MC-1..	Thinned out 1:1 by weight with T25; three coats brushed on	2.5	E	820
	Thinned out 1:1 with T25; nine coats brushed on	12.5	D	15
	Thinned out 3:1 by weight with T25; one coat brushed on	9.5	D	23
	Thinned out 2:1 by weight with T25; two coats brushed on	10	C	10
L-NS-1..	One coat applied with doctor blade	([b])	C	2
L-NS-2..	One coat brushed on	15	C	<1
L-PP-1..	Two coats brushed on	7.5	E	696
	.....do	7	E	814
	Five coats brushed on	25	A	<1
L-RF-1..	Three coats brushed on	1.5	E	645
	Four coats brushed on	5.5	D	37
	Nine coats brushed on	11.5	C	7
	Five coats brushed on	20	E	1,190
L-RF-2..	.....do	9	E	900
L-SC-1..	Three coats brushed on	5.5	E	898
	.....do	5.5	E	835
	One coat applied with doctor blade	8.5	D	318
	Six coats brushed on	9	D	260
	Four coats applied with doctor blade	20	C	45
	Four coats brushed on; dried 2 weeks	26	E	788
L-WP-1..	One coat brushed on	3.5	E	978
	Two coats brushed on	10	E	1,100
	Four coats brushed on	25	E	934
L-WW-1..	One coat applied with doctor blade	6.5	E	984

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.
[b] Dried too unevenly to determine.

TABLE 11.—*Vacuum-impact tests made on glass treated with plastic sheetings*

Sample designation	Method of application to glass[b]	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
S-EI-1..	Coat of A adhesive brushed on glass; sheeting rolled on over A	15	A	<1
	Coat of B adhesive brushed on glass; sheeting rolled on over B	15	A	<1
S-El-2..	P	5	D	325
S-El-3..	P	10	E	500
S-EI-4..	P	15	C	25
S-El-5..	P	20	D	23
S-El-6..	P	25	D	5
S-LO-1..	P	20	A	<1
S-LO-2..	P	30	A	<1
S-LO-3..	P	45	A	<1
S-LO-4..	P	60	A	<1
S-LO-5..	P	15	C	56
S-MC-1..	P	25	A	<1
S-MC-2..	P	25	B	25
S-MC-3..	P	15	C	15
S-MC-4..	P	15	A	2
S-MC-5..	P	8	B	<1
S-MC-6..	P	8	B	<1
S-Sl-1..	Glass pane wet with water; sheet of S-Sl-1 rolled on	2.5	E	905
	Glass wet with water; two sheets of S-Sl-1 rolled on	5	D	300
	.....do	5	E	900
	Glass wet; three sheets rolled on	7.5	E	660
	Two sheets rolled on each side of wet glass	[c] 10	E	800
	Glass wet; four sheets rolled on	10	C	35
	Glass wet; one sheet rolled on; two diagonal lines, from opposite corners cut into S-SI-1 with knife.	2.5	C	60
S-Sl-1..	Glass wet; two sheets rolled on diagonals cut	5	....	2
	One sheet pressed on glass with a warm iron	2.5	E	790
	Four sheets pressed on with warm iron	10	B	10
	.....do	10	D	270
	Six sheets pressed on with warm iron	15	B	25
S-TP-1..	Waxed paper pulled off film as film was rolled on glass; 48 hr drying time	2	E	870

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc. [b] P = treatments applied to glass by manufacturers in their laboratories. [c] 5 mils on each side.

TABLE 12.—*Vacuum-impact tests made on glass treated with tapes*

Sample designation	Method of application to glass	Description of break[a]	Weight of fragments of glass in basket
			Grams
T-GP-1....	Basket-weave pattern; strips applied 1 in. apart	D	50
	Overlapping strips applied to glass widthwise	C	259
	Overlapping strips applied to glass lengthwise	E	952
T-GP-2....	Basket-weave pattern; strips applied 2 in. apart	D	104
	Overlapping strips applied widthwise	E	1,002
	Overlapping strips applied lengthwise	D	37
	Overlapping strips applied lengthwise; 4 in. slit cut in center widthwise	C	55
T-GP-3....	Parallel strips 1 in. apart, applied lengthwise	E	800
	Four strips applied in Union Jack pattern	E	800
	Basket-weave pattern; strips applied 1 in. apart	C	70
	Basket-weave pattern; strips applied 2 in. apart, reinforced at edges	E	450
	Overlapping strips applied lengthwise to glass	D	103
	Overlapping strips applied widthwise	E	1,110
	Overlapping strips applied lengthwise; 4 in. slit in center widthwise	C	10
	Overlapping strips applied lengthwise; pattern cut	C	10
T-GP-4....	Basket-weave pattern; strips applied 2 in. apart	C	55
	Overlapping strips applied lengthwise; pattern cut	D	180
	Overlapping strips applied widthwise; pattern cut	C	7
	Overlapping strips applied widthwise	C	35
	Overlapping strips applied lengthwise	D	295
	Overlapping strips applied widthwise; 5 in. slit in center lengthwise	C	30
	Overlapping strips applied widthwise; pattern cut	C	10
T-GP-5....	Basket-weave pattern; 1 in. between strips	D	450
T-GP-6....	Basket-weave; 1-in. space between strips	D	435
T-GP-7....	.....do	E	680
T-1P-1....	.....do	E	734
T-1P-2....	Strips applied lengthwise, 3/4 in. between each; insufficient material for basket-weave pattern.	E	925
T-1P-4....	Basket-weave pattern; all strips applied lengthwise first, then widthwise	E	770
	Basket-weave; alternating 1 strip lengthwise, 1 widthwise	D	405
T-1P-6....	Basket-weave; 2-in. space between strips	E	690
T-IP-7....	Overlapping strips applied lengthwise	E	825
T-1P-8	Basket-weave, 75% coverage	E	925
T-1P-10...	Basket-weave; 2-in. space between strips	E	655
T-IP-11...	Overlapping strips applied lengthwise	E	865
T-MS-1....	Basket-weave; 1-in. space between strips	D	65
T-MS-2....	Basket-weave; 2-in. space between strips	B	48
T-MS-3....	Basket-weave; 1 in. between strips; rope removed from strips 1 in. from ends	E	897
T-MS-4....	Basket-weave; 2-in. space between strips; rope removed from strips 1 in. from ends	E	855
T-MM-1....	Basket-weave; 1-in. space between strips	E	790
T-MM-2....	Basket-weave; 2-in. space between strips	E	700
T-MM-3....	.....do	E	825
T-MM-3....	Overlapping strips applied lengthwise	D	35
T-MM-3....	Overlapping strips applied widthwise	E	835
T-MM-3....	Overlapping strips applied lengthwise	C	90
T-MM-3....	Overlapping strips applied lengthwise; reinforced around border with extra strips	C	40
T-MM-4....	Basket-weave pattern; 2-in. space between strips	E	840
T-MM-5....	.....do	E	785
T-MM-6....	Basket-weave; 2-in. space between strips	E	915
T-MM-7....	Overlapping strips applied lengthwise	E	510
		E	590
T-MM-8....	.....do	E	750
T-MM-9....	.....do	C	5
		C	3
T-MM-10...	.....do	D	66
		E	410
T-MM-11...	.....do	D	5
		E	820
		D	387
T-PB-2....	Basket-weave pattern; 1/2 in. between strips	E	785
T-PB-3....	Basket-weave pattern; 1 1/2 in. between strips	D	365

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 13.—*Vacuum-impact tests made on glass treated with fabrics, and adhesives specified for fabrics*

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
F-AM-1 L-MC-1	Coat of L-MC-1 applied to glass. Two halves of F-AM-1 smoothed over	....	E	920
F-AR-1	F-AR-1 spread on glass	12-18	E	865
F-CS-1	Rolled on glass	....	D	450
F-DC-1	Coat of adhesive brushed on. F-DC-1 pressed down over it	....	E	800
F-IT-1	F-IT-1 applied to glass with water	....	E	695
F-IT-2 L-GI-1	L-GI-1 brushed on glass. F-IT-2 smoothed over. Another coat L-GI-1 applied	....	D	8
F-LO-1	([b])	....	B	10
F-MA-1 F-AR-1	F-AR-1 spread on glass. F-MA-1 smoothed over	....	C	3
F-MA-1 L-MC-1	L-MC-1 brushed on glass. F-MA-1 smoothed over	....	C	40
F-MA-1 L-RF-2	L-RF-2 brushed on glass. F-MA-1 smoothed over. Two more coats L-RF-2 brushed on	....	A	<1
F-MA-1 L-RF-2	.....do	....	F	<1
F-MA-1 L-SC-1	Coat of L-SC-1 brushed on. F-MA-1 smoothed over. One more coat L-SC-1 brushed on	....	F	<1
F-MA-1 Z-1	Z-1 spread on glass. F-MA-1 smoothed over	....	F	<1
F-MA-2 F-MP-1	F-MP-1 spread on glass. F-MA-2 pressed down over	....	B	<1
F-MC-1	([b])	....	B	<1
F-MF-1 F-AR-1	F-AR-1 spread on glass. F-MF-1 smoothed on	....	E	545
F-MF-1 F-AR-1	.....do	....	E	440
F-MF-1 L-EI-2	L-EI-2 brushed on glass. F-MF-1 smoothed over. Another coat L-EI-2 brushed on	9	D	6
F-MF-1 L-GI-1	L-GI-1 brushed on glass. F-MF-1 smoothed over. Another coat of L-GI-1 brushed on	8	D	9
F-MF-1 Z-1	Z-1 spread on glass. F-MF-1 smoothed over	....	D	40
F-MF-1 Z-2	Z-2 spread on glass. F-MF-1 smoothed over	....	D	30
F-MF-2 F-AR-1	F-AR-1 spread on glass. F-MF-2 smoothed over	....	E	860
F-MF-2 F-AR-1	.....do	....	D	4
F-MF-2 L-EI-2	L-EI-2 brushed on glass. F-MF-2 smoothed over	8	D	24
F-MF-2 L-EI-2	L-EI-2 brushed on glass. F-MF-2 smoothed over. Another coat L-EI-2 brushed on	15	B	5
F-MF-2 L-GI-1	L-GI-1 lacquer brushed on glass. F-MF-2 smoothed over	9	B	5
F-MF-2 L-RF-2	L-RF-2 brushed on glass. F-MF-2 smoothed on. Two more coats L-RF-2 brushed on	8	D	66
F-MF-2 L-SC-1	L-SC-1 brushed on glass. F-MF-2 smoothed over. Two more coats L-SC-1 applied	15	C	165
F-MF-2 Z-3	Z-3 spread on glass. F-MF-2 smoothed over	....	D	20
F-MF-2 Z-4	Z-4 spread on glass. F-MF-2 smoothed over	....	A	....
F-XX-1 F-AR-1	F-AR-1 spread on glass. F-XX-1 smoothed over	....	D	38
F-XX-1 F-AR-1	.....do	....	D	25
F-XX-1 F-NS-1	F-NS-1 brushed on glass. F-XX-1 smoothed over	....	D	180
F-XX-1 F-NS-3	F-NS-3 brushed on glass. F-XX-1 smoothed over	....	D	8
F-XX-1 F-NS-4	F-NS-4 brushed on glass. F-XX-1 smoothed over	....	D	243
F-XX-1 L-GI-1	L-GI-1 brushed on glass. F-XX-1 smoothed over	....	D	25
F-XX-1 L-SC-1	L-SC-1 brushed on glass, F-XX-1 smoothed over	....	E	405
F-XX-2 L-NS-2	F-XX-2 stretched over glass. L-NS-2 brushed on	....	D	2

[a] The descriptions of break corresponding to the various letter designations are described in the text on p. 5. A is the most preferred type of break; B is next, etc.

[b] Treatments applied to glass by manufacturers in their laboratories.

TABLE 13.—*Vacuum-impact tests made on glass treated with fabrics, and adhesives specified for fabrics*—Con.

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
F-XX-2 F-NS-2	F-XX-2 stretched over glass. F-NS-2 brushed on	....	E	580
F-XX-2 F-NS-3	F-NS-3 brushed on glass. F-XX-2 smoothed over	....	E	625
F-XX-2 L-RF-2	L-RF-2 brushed on glass. F-XX-2 smoothed over. Two coats L-RF-2 brushed on	10-15	E	800
F-XX-2 Z-1	Z-1 spread on glass. F-XX-2 smoothed over	....	E	940
F-XX-2 Z-2	Z-2 spread on glass. F-XX-2 smoothed over	....	D	28
F-XX-2 Z-3	Z-3 spread on glass. F-XX-2 smoothed over	....	D	10
F-XX-3 F-AR-1	F-AR-1 spread on glass. F-XX-3 smoothed on	....	B	< 1
F-XX-3 F-AR-1	.....do	....	C	10
F-XX-3 F-AR-1	.....do	....	D	176
F-XX-3 F-AR-1	.....do	....	D	175
F-XX-3 F-AR-1	.....do	....	D	117
F-XX-3 F-AR-1 L-CP-2	F-AR-1 spread on glass. F-XX-3 smoothed over. L-CP-2 brushed on	....	C	< 1
F-XX-3 F-AR-1 L-CP-2	F-AR-1 spread on glass. F-XX-3 smoothed over. Four coats L-CP-2 brushed on	....	F	5
F-XX-3 F-AR-1 L-EI-2	F-AR-1 spread on glass. F-XX-3 smoothed over. L-EI -2 brushed on	....	D	12
F-XX-3 F-AR-1 L-GI-1	F-AR-1 spread on glass. F-XX-3 smoothed over. Four coats L-GI-1 brushed on	....	F	< 1
F-XX-3 F-AR-1 L-GI-1	F-AR-1 spread on glass. F-XX-3 smoothed over. One coat L-GI-1 brushed on	....	E	1,306
F-XX-3 L-CP-2	Thin coat L-CP-2 brushed on glass. F-XX-3 smoothed over	....	A	< 1
F-XX-3 L-CP-2	.....do	....	D	221
F-XX-3 L-CP-2	.....do	....	D	205
F-XX-3 L-CP-2	.....do	....	D	156
F-XX-3 L-CP-2	.....do	....	D	15
F-XX-3 L-CP-2	L-CP-2 brushed on glass. F-XX-3 smoothed over. Another coat L-CP-2 brushed on	....	D	140
F-XX-3 L-CP-2	Two coats L-CP-2 brushed on. F-XX-3 smoothed over. Two more coats L-CP-2 applied	....	D	47
F-XX-3 L-CP-2	.....do	....	D	52
F-XX-3 L-CP-2	L-CP-2 brushed on glass. F-XX-3 smoothed over. Four coats L-CP-2 brushed on	....	B	< 1
F-XX-3 L-CP-2	Three coats L-CP-2 brushed on glass. F-XX-3 smoothed over	....	D	175
F-XX-3 L-CP-2	Three coats L-CP-2 brushed on glass. F-XX-3 smoothed over. Three more coats L-CP-2 brushed on.	....	A	< 1
F-XX-3 L-CP-2	.....do	....	D	97
F-XX-3 L-CP-2	.....do	....	D	160
F-XX-3 L-GI-1	One thin coat L-GI-1 brushed on. F-XX-3 smoothed over	....	B	< 1
F-XX-3 L-GI-1	Thin coat L-GI-1 brushed on glass. F-XX-3 smoothed over	....	E	800
F-XX-3 L-GI-1	.....do	....	E	620
F-XX-3 L-GI-1	Five coats L-GI-1 brushed on glass. F-XX-3 smoothed over	12	D	21
F-XX-3 L-GI-1	Three coats L-GI-1 brushed on glass. F-XX-3 smoothed over	....	D	36

[a] The descriptions of break corresponding to the various letter designations are described in the text on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 13.—*Vacuum-impact tests made on glass treated with fabrics, and adhesives specified for fabrics*—Con.

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
F-XX-3 L-GI-1	Two coats L-GI-1 brushed on glass. F-XX-3 smoothed over. Another coat L-GI-1 brushed on.	....	D	15
F-XX-3 L-GI-1	Two coats L-GI-1 brushed on. F-XX-3 smoothed over	....	G	< 1
F-XX-3 L-GI-1	Two coats L-GI-1 brushed on. F-XX-3 smoothed over. Two more coats L-GI-1 brushed on	....	D	30
F-XX-3 L-GI-1	L-GI-1 brushed on. F-XX-3 smoothed over. Another coat L-GI-1 brushed on	....	D	10
F-XX-3 L-GI-1	L-GI-1 brushed on glass. F-XX-3 smoothed over. Three additional coats L-GI-1 brushed on.	....	F	< 1
F-XX-3 L-GI-1	Three coats L-GI-1 brushed on glass. F-XX-3 smoothed over. Two coats L-GI-1 brushed on.	....	D	15
F-XX-3 L-SC-1	Thin coat L-SC-1 brushed on glass. F-XX-3 smoothed over	....	E	595
F-XX-3 Z-1	Z-1 spread on glass. F-XX-3 smoothed over	....	E	800
F-XX-3 Z-1	....do	....	F	< 1
F-XX-3 Z-1	....do	....	A	< 1
F-XX-3 Z-1 L-CP-2	Z-1 spread on glass. F-XX-3 smoothed over. Two coats L-CP-2 brushed on	....	D	370
F-XX-3 Z-2	Z-2 spread on glass. F-XX-3 smoothed over	....	C	67
F-XX-3 Z-3	Z-3 spread on glass. F-XX-3 smoothed over	....	F	< 1
F-XX-3 Z-3	....do	....	F	< 1
F-XX-3 Z-3	....do	....	F	< 1
F-XX-3 Z-4	Z-4 spread on glass. F-XX-3 smoothed over	....	A	< 1
F-XX-3 Z-4	....do	....	A	< 1
F-XX-3 Z-4	....do	....	A	< 1
F-XX-3 Z-5	Z-5 spread on glass. F-XX-3 smoothed over	....	A	< 1
F-XX-3 Z-5	....do	....	A	< 1
F-XX-4 L-CP-2	L-CP-2 brushed on glass. F-XX-4 smoothed over. Another coat L-CP-2 brushed on	15	E	682
F-XX-4 L-CP-2	....do	15	E	560

[a] The descriptions of break corresponding to the various letter designations are described in the text on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 14.—*Vacuum-impact tests made on glass treated with asphalt-asbestos combinations*

Sample designation	Method of application to glass[a]	Film thickness	Description of break[b]	Weight of fragments of glass in basket
		Mils		*Grams*
A-JM-1	P	....	C	30
A-JM-2	P	....	A	< 1
A-JM-3	P	66.5	D	2
A-JM-4	P	....	D	4

[a] P = Treatments applied to glass by manufacturers in their laboratories.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break, B is next, etc.

TABLE 15.—*Vacuum-impact tests made on glass treated with combinations of liquid materials, films, and tapes*

Sample designation	Method of application to glass	Film thickness	Description of break[a]	Weight of fragments of glass in basket
		Mils		*Grams*
L-CP-1 T-GP-3	Coat of L-CP-1 brushed on and allowed to dry. Strips of T-GP-3 applied in basket-weave pattern 2" between strips.	3.5 (L-CP-1)	E	950
L-CP-1 T-GP-4	.....do	3.5 (L-CP-1)	D	135
L-GI-1 S-SI-1	One coat L-GI-1 brushed on and allowed to dry. One sheet S-SI-1 pressed on with warm iron.	6	D	146
	Same as above, except that four sheets of S-SI-1 were pressed on	14	C	45
L-GI-1 T-GP-3	Coat of L-GI-1 brushed on and allowed to dry. Strips of T-GP-3 applied in basket-weave pattern 2" between strips.	3.5 (L-GI-1)	F	183
L-GI-1 T-GP-3	.....do	6.5 (L-GI-1)	C	115
L-GI-1 T-GP-4	.....do	4 (L-GI-1)	D	117
L-GI-1 T-MM-9	Coat of L-GI-1 brushed on and allowed to dry. Overlapping strips of T-MM-9 applied lengthwise.	3.5 (L-GI-1)	C	20
L-MC-1 S-DC-1	Coat of L-MC-1 brushed on glass followed by S-DC-1 film rolled on over the L-MC-1.	6	D	185
L-MC-1 S-MC-7	Coat of L-MC-1 brushed on. Film S-MC-7 rolled on over L-MC-1	7.5	E	945
L-NS-3 S-CC-1	Adhesive L-NS-3 brushed on glass, followed by S-CC-1 film rolled over the L-NS-3.	4.5 (S-CC-1) 4.5 (S-CC-1)	B C	< 1 20
L-NS-3 S-CC-2	Adhesive L-NS-3 brushed on glass, followed by S-CC-2 film rolled on over L-NS-3.	3.5 (S-CC-2)	D	3
L-SC-1 T-GP-3	Coat of L-SC-1 brushed on and allowed to dry. Strips of T-GP-3 applied in basket-weave pattern 1" between strips.	4 (L-SC-1)	B	5
L-SC-1 T-GP-3	T-GP-3 applied in basket-weave pattern 2" between strips. 2 coats L-SC-1 brushed on	....	E	330
	T-GP-3 applied in basket-weave pattern 1" between strips. 2 coats L-SC-1 brushed on	....	C	60

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break, B is next, etc.

TABLE 16.—*Vacuum-impact tests made on treatments applied to single strength window glass, 7/32-inch glass, plate glass, and tempered glass*

Sample designation	Method of application to glass[a]	Film thickness	Description of break[b]	Weight of fragments of glass in basket
		Mils		*Grams*
P-AW-1	P	....	E	1,020
P-LO-1	P	30	A	< 1
P-LO-2	P	45	A	< 1
P-LO-3	P	60	A	< 1
P-LO-4	P	20	C	56
P-LO-5	P	30	F (28" Hg)	< 1
P-LO-7	P	60	F (28" Hg)	< 1
P-LO-8	P	15	D (24" Hg)	378
P-LO-9	P	20	(c)	....
P-LO-10	P	15	(c)	....
P-LO-11	P	....	C	88
P-MC-1	P	25	B	5
P-MC-2	P	25	A	< 1
P-MC-3	P	15	B	< 1
P-MC-4	P	15	A	< 1
P-MC-5	P	8	A	< 1
P-MC-6	P	8	D	5
P-MC-7	P	....	C	16

[a] P = treatments applied to glass by manufacturers in their laboratories.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.
[c] Did not break.

TABLE 17.—*Vacuum-impact tests made on special glass products*

Sample designation	Type of glass	Manometer reading	Description of break[a]	Weight of fragments of glass in basket
				Grams
G-AW-1	Double-strength	20	E	925
G-PG-1	Single-strength	20	E	725
G-PG-2	Double-strength	20	E	940
G-PG-3	Glazing quality	20	E	1,710
G-LO-1	Tempered	20;24;28	([b])	....
G-PG-5	.....do	20;24;28	([b])	....
G-MG-1	Polished wire glass	28	E	1,987
G-MG-2	Hammered wire glass	20	E	1,740
G-AW-2	Double and single	20	E	1,360
G-AW-3	7/32" and lantern slide	24	E	1,962
G-LO-2	Laminated	20;24;28	([b])	....
G-PG-6	.....do	20	A	<1
G-PG-7	.....do	20 20	E B	960 8
G-PG-8	.....do	20 20	D D	75 10
G-PG-9	.....do	20	E	1,320
G-AW-5	Single-strength double-glazed unit	20	A	<1

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.
[b] Did not break.

TABLE 18.—*Vacuum-impact tests made on replacements for glass in window enclosures*

Sample designation	Description of break[a]	Weight of fragments of material in basket
		Grams
R-JM-1	C	<1
R-JM-2	D	<1
R-JM-3	D	<1
R-JM-4	D	686
R-MC-1	A	<1

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 19.—*Vacuum-impact tests made on glass treated with liquid materials and subjected to cycles of high and low humidity (accelerated aging test I,*

Sample designation	Film thickness	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
	Mils			
L-EI-2	25	No change	A	<1
L-GI-1	24	.....do	B	3
L-GI-2	40	.....do	B	2
L-CP-1	23	Peeled off entirely	([c])	([c])
L-SC-1	24	Bond weakened; little peeling	F	2
L-RF-2	20	Peeled around edges less than 6 in	E	1,287

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.
[c] No vacuum-impact test possible.

TABLE 20.—*Vacuum-impact tests made on glass treated with plastic sheets and subjected to cycles of high and low humidity (accelerated aging test I)*

Sample designation	Film thickness	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
	Mils			*Grams*
S-EI-1...	15	No change	A	<1
S-EI-3...	10	.....do	C	5
S-EI-4...	15	.....do	B	3
S-EI-5...	20	.....do	A	2
S-LO-1...	20	.....do	A	3
S-LO-5...	15	.....do	B	17
S-MC-6...	8	Cellulose acetate sheet peeled off vinyl resin layer. Vinyl resin did not change...	A	3
S-SI-1...	10	Peeled around edges less than 6". Peeled in spots; wavy surface	D	51
S-CC-1...	....	.....do	D	379

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 21.—*Vacuum-impact tests made on glass treated with tapes and subjected to cycles of high and low humidity (accelerated aging test I)*

Sample designation	Method of application to glass	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
				Grams
T-GP-1....	Basket-weave strips 1" apart	No change	D	88
T-GP-2....	Basket-weave strips 2" apart	.....do	D	16
T-GP-3....	Basket-weave strips 1" apart	Peeled around edges less than 2"	D	45
T-GP-3....	Overlapping strips applied lengthwise...	.....do	A	<1
T-GP-4....	Basket-weave strips applied 2" apart....	.....do	B	15
T-GP-4....	Overlapping strips applied widthwise....	.....do	A	<1
T-MS-1....	Basket-weave strips applied 1" apart....	.....do	D	87
T-MS-2....	Basket-weave strips 2" apart	No change	C	65
T-MM-3....	Overlapping strips applied lengthwise...	Peeled around edges less than 6". Peeled in spots; wavy surface.	E	386
T-MM-9....	.....do	Tape shrank	A	<1
T-MM-11...	.....do	No change	D	241

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 22.—*Vacuum-impact tests made on glass treated with fabrics and adhesives specified for fabrics and subjected to cycles of high and low humidity (accelerated aging test I)*

Sample designation	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
			Grams
F-LO-1	No change	A	<1
F-MC-1	.....do	A	<1
F-AR-1 F-XX-3	.....do	C	12
F-AR-1 F-XX-3 L-EI-2	.....do	D	65
L-EI-2 F-MF-2	.....do	C	15

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 23.—*Vacuum-impact tests made on glass treated with asphalt-asbestos combinations and subjected to cycles of high and low humidity (accelerated aging test I)*

Sample designation	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
			Grams
A-JM-1	No change	A	5
A-JM-2	....do	A	2
A-JM-3	....do	D	3
A-JM-4	....do	D	10

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 24.—*Vacuum-impact tests made on special glass products subjected to cycles of high and low humidity (accelerated aging test I)*

Sample designation	Appearance after accelerated aging test I[a]	Description of break[b]	Weight of fragments of glass in basket
			Grams
G-AW-5	No change	B	2

[a] Accelerated aging test I was made by exposing the treated glass panes to 10 repeated cycles of 7 hr in a fog chamber at 70° F, followed by 17 hr at ordinary interior conditions.
[b] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 25.—*Vacuum-impact tests made on glass treated with liquid materials and subjected to heat aging (accelerated aging test II)*

Sample designation	48 hours at 160° F: Film thickness	48 hours at 160° F: Description of break[a]	48 hours at 160° F: Weight of fragments of glass in basket	168 hours at 160° F: Film thickness	168 hours at 160° F: Description of break[a]	168 hours at 160° F: Weight of fragments of glass in basket
	Mils		*Grams*	*Mils*		*Grams*
L-E1-2	32	A	....	24	D	185
L-G1-1	20	B	3	14	F	3
	25	A	1	22	A	<1
L-G1-2	26	A	1	26	A	<1
L-CP-1	20	E	1,190	21	E	1,145
L-SC-1	24	E	785	21	E	1,025

[a] The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 26.—*Vacuum-impact tests made on glass treated with plastic sheets and subjected to heat aging (accelerated aging test II)*

Sample designation	48 hours at 160° F: Film thickness	48 hours at 160° F: Description of break[a]	48 hours at 160° F: Weight of fragments of glass in basket	168 hours at 160° F: Film thickness	168 hours at 160° F: Description of break[a]	168 hours at 160° F: Weight of fragments of glass in basket
	Mils		*Grams*	*Mils*		*Grams*
S-E1-1	15	C	2	15	D	8
S-EI-3	10	E	725	....	....	....
S-E1-4	....	....	....	15	B	<1
S-LO-1	20	A	1	20	A	<1
P-LO-8	15	D	265	....	....	....
S-LO-5	....	....	....	15	C	2
P-MC-1	25	A	1	....	....	....
S-MC-1	....	....	....	25	A	2
S-S1-1	10	D	260	10	E	880
S-CC-1	....	D	14	....	D	18

[a] The descriptions of break corresponding to the various letter designations are described in the text on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 27.—*Vacuum-impact tests made on glass treated with tapes and subjected to heat aging (accelerated aging test II)*

Sample designation	Method of application to glass	48 hours at 160° F		168 hours at 160° F	
		Description of break[a]	Weight of fragments of glass in basket	Description of break[a]	Weight of fragments of glass in basket
T-GP-1	Basket-weave strips 1" apart	E	741	E	582
T-GP-2	Basket-weave strips 2" apart	E	470	E	638
T-GP-3	Overlapping strips applied lengthwise	D	147	D	303
T-GP-3	Basket-weave strips 1" apart	E	1,085	D	25
T-GP-4	Basket-weave strips 2" apart	E	685	B	20
T-GP-4	Overlapping strips widthwise	A	1	A	<1
T-MS-1	Basket-weave strips 1" apart	E	576	E	595
T-MM-3	Overlapping strips applied lengthwise	E	535	D	72
T-MM-9	.....do	E	425	E	510
T-MM-11	.....do	E	715	E	567

[a]The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 28.—*Vacuum-impact tests made on glass treated with fabrics and adhesives specified for fabrics, and subjected to heat aging (accelerated aging test II)*

Sample designation	Method of application to glass	48 hours at 160° F		168 hours at 160° F	
		Description of break[a]	Weight of fragments of glass in basket	Description of break[a]	Weight of fragments of glass in basket
			Grams		*Grams*
F-LO-1	P[b]	A	2	A	<1
L-SC-1 F-XX-3	L-SC-1 brushed on glass. F-XX-3 smoothed over. Two more coats L-SC-1 applied.	....	....	F	<1
L-EI-2 F-MF-2	L-EI-2 brushed on glass. F-MF-2 smoothed over. Two more coats L-EI-2 applied.	....	....	B	20
F-AR-1 F-XX-3 L-EI-2	F-AR-1 applied to glass. F-XX-3 smoothed over. Coat of L-EI-2 brushed on.	....	....	D	60
L-RF-2 F-XX-3	L-RF-2 brushed on glass. F-XX-3 smoothed over. Two more coats L-RF-2.	....	....	E	800
F-AR-1 F-XX-3	F-AR-1 applied to glass. F-XX-3 smoothed over.	....	....	C	5

[a]The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.
[b]P=treatments applied to glass by manufacturers in their laboratories.

TABLE 29.—*Vacuum-impact tests on glass treated with asphalt-asbestos combinations and subjected to heat aging (accelerated aging test II)*

Sample designation	48 hours at 160° F		168 hours at 160° F	
	Description of break[a]	Weight of fragments of glass in basket	Description of break[a]	Weight of fragments of glass in basket
		Grams		*Grams*
A-JM-1	D	160	D	8
A-JM-2	....	....	A	<1
A-JM-3	....	....	B	65
A-JM-4	C	10	A	4

[a]The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 30.—*Vacuum-impact tests on special glass products subjected to heat aging (accelerated aging test II)*

Sample designation	48 hours at 160° F		168 hours at 160° F	
	Description of break[a]	Weight of fragments of glass in basket	Description of break[a]	Weight of fragments of glass in basket
		Grams		*Grams*
G-AW-5	B	1	D	35

[a]The descriptions of break corresponding to the various letter designations are described on p. 5. A is the most preferred type of break; B is next, etc.

TABLE 31.—*Summary of results of tests made with glass coated with lacquer*

Resin base of lacquer	Number of tested samples	Good breaks	
		Initially	After aging
Acrylic	2	0	0
Cellulose nitrate	1	1	0
Chlorinated rubber	1	0	0
Ethylcellulose	5	0	0
Polyvinyl acetate	5	3	0
Polyvinyl butyral	7	5	2
Protein	1	1	0
Reclaimed rubber	1	0	0
Unknown	3	0	0
Total	26	10	2

WASHINGTON, July 3, 1943

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